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ABSTRACT

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TECH MEMO

THE INTERACTIVE EFFECTS OF THE AVAILABILITY OF OBJECTIVES AND/OR RULES ON COMPUTER-BASED LEARNING: A REPLICATION

Paul F. Merrill, Michael H. Steve, Stanley J. Kalisch, and Nelson J. Towle

Tech Memo No. 59
September 15, 1972
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THE INTERACTIVE EFFECTS OF THE AVAILABILITY OF OBJECTIVES AND/OR RULES ON COMPUTER-BASED LEARNING: A REPLICATION[1]

Paul F. Merrill, Michael H. Steve, Stanley J. Kalisch,
and Nelson J. Towle
Florida State University

The effects of the availability of objectives and/or rules on the learning process were investigated by Merrill (1970) using an imaginary science as the learning task. Merrill found that the presentation of rules reduced the number of examples and total time required to complete the task and increased performance on a transfer test. The availability of objectives reduced test item response latency and the number of examples required to meet criterion performance. An objective by rule interaction with test item response latency as criterion revealed that objectives had a greater effect in reducing response latency when added to a task which had no other focusing or organizing stimuli than they did when added to a task which had other effective oriented stimuli such as rules. Ability by treatment interactions were obtained using test item response latency as criterion and reasoning ability test scores as covariables. These interactions showed that the availability of objectives and/or rules significantly reduced the requirements for reasoning ability in responding to test

[1]Paper presented at the annual meeting of the American Psychological Association, Honolulu, Hawaii, September, 1972.

items. The purpose of this study was to replicate and extend the results of the previous study using an actual classroom task rather than an imaginary science.

Based on the results of the previous study, it was hypothesized that the presentation of objectives and/or rules would significantly reduce the number of examples required to reach criterion performance and would reduce the requirements for reasoning ability. Rules were also expected to reduce display latency, reduce test item response latency, reduce post, retention, and transfer latencies, and increase performance on a transfer test. Objectives were expected to reduce test item response latency. As an extension to the previous study, it was further hypothesized that objectives and/or rules would reduce state anxiety within the task (Merrill & Towle, 1972).

Method

Subjects

The 140 S's who participated in this study were volunteers from introductory psychology and math education classes at The Florida State University. However, seven of the original Ss were eliminated from the data analysis because they failed to complete all phases of the study.

Aptitude Measures

Two cognitive ability tests and a trait anxiety scale were administered to all Ss in group testing sessions. Based on their relevance to the task, the Letter Sets and Ship Destination cognitive ability tests were selected from the Kit of Reference Tests for Cognitive Factors (French, Ekstrom, & Price, 1963). The trait anxiety scale used was the STAI A-Trait scale developed by Spielberger, Gorsuch, and Lushene (1970). A short form of the STAI A-State scale (O'Neil, 1970) was given at three points during the task

Experimental Tasks and Materials

The learning task used in this study was developed by the authors utilizing eight rules based on the primitive mixed functions of the APL Programming Language (McMurchie, Krueger, & Lippert, 1970). Rules from the APL language were selected as the learning task since APL is currently being taught in college courses across the country, while the uniqueness of APL makes it possible to easily screen Ss who have had previous experience with the language. The instructional program consisted of a module for each of the eight rules ordered in a subjectively determined easy-to-hard sequence. The materials for each module included a statement of an objective, a statement of a rule, five examples of the rule, and five short constructed response tests. Each test consisted of three items which required Ss to apply the appropriate rule The rule and objective statements, examples, and sample test items may be found in Appendix A.

The post- and retention tests used in this study consisted of 24 constructed response items similar to the items used in the module tests. Both tests contained three items for each of the eight rules in the program The transfer task consisted of two examples and three constructed response test items for eight new rules which were logical extensions of the rules used in the original task. The Ss were required to infer each new rule from the examples and apply the inferred rule in the three test items. The transfer test score was the total number of test items answered correctly by Ss. An example and test item for each of the eight transfer rules are included in Appendix B.

The instructional program and tests were written in the Coursewriter II language and presented on a cathode ray tube terminal by the IBM 1500/1800 computer-assisted instruction system.

Procedure

After the administration of the two ability tests and the STAI A-Trait scale, each S was randomly assigned to one of four treatment groups: an example-only group (n = 33), an objective-example group (n = 33), a rule-example group (n = 34), or an objective-rule-example group (n = 33). Figure 1 is a graphical representation of the 2 x 2 factorial design formed by these groups. In learning the APL rules, Ss in the example-only group received an example of the first rule displayed on a cathode ray tube terminal. After studying the example, each S responded to a three-item constructed response test in which he was required to predict certain values using the rule inferred from the example. If the S responded correctly to at least two of the three test items, he was given an example of the next rule in the sequence. Otherwise he was given another example of the same rule followed by three more test items. This sequence of an example, followed by a test, continued until the S answered at least two of the three test items correctly, or until he received five examples of the rule. This procedure was repeated for all eight modules of the task. A computer-administered posttest was presented immediately following completion of the learning task, and computer-administered retention and transfer tests were presented two weeks later.

The Ss in the other three groups were presented the APL rules by the same basic procedure, except for the following treatment differences. The objective-example group received a statement of an objective in addition to the corresponding example; the rule-example group received a statement of the rule in addition to the corresponding example; and the objective-rule-example group received statements of both the objective and the rule in addition to the example. The five-item STAI A-State scale was presented via computer terminal to all Ss prior to the learning task, immediately following the fourth module, and again following the final module.

OBJECTIVES	RULES: NO	RULES: YES
NO	EXAMPLE ONLY (n = 33)	RULE-EXAMPLE (n = 34)
YES	OBJECTIVE-EXAMPLE (n = 33)	OBJECTIVE-RULE-EXAMPLE (n = 33)

Figure 1.--2 x 2 Factorial Design Used in this Study.

Results

In addition to the total scores on the two cognitive ability tests, STAI A-trait scale, STAI A-state scale, posttest, retention test, and transfer test mentioned in the procedures section, data were obtained for each S on the following criteria: total number of examples required to learn the APL rules, display latency, post-, retention, and transfer test item response latencies. Test item response latency was the total time required by Ss to respond to the three-item tests following each example display. Display latency was the total time spent studying the examples, and depending upon S's treatment group, the corresponding rules and/or objectives.

Descriptive statistics and reliability coefficients for the ability tests, the A-Trait scale, and the three administrations of the A-State scale are found in Table 1. The reliability coefficients of the A-Trait and A-State scales were estimated using coefficient alpha. The reliability coefficients of the ability tests were estimated using the Kuder-Richardson Formula 20 (KR-20). Although the ability tests were not pure speeded tests, they were timed. Therefore, these reliability coefficients should be interpreted with caution. Using formula KR-20, the reliability coefficients of the post-, retention, and transfer tests, which were not speeded, were estimated to be .89, .85, and .87, respectively.

TABLE 1

Descriptive Statistics of Ability, A-Trait, and A-State Measures

TESTS	NUMBER OF ITEMS	MEANS	S.D.	RELIABILITY
Letter Sets Test	15	10.1	2.3	.69[a]
Ship Destination	24	12.8	4.5	.86[a]
A-Trait	20	37.8	8.3	.87[b]
A-State (Pre-task)	5	9.8	3.3	.84[b]
A-State (Mid-task)	5	9.5	3.8	.88[b]
A-State (Post-task)	5	11.8	4.8	.92[b]

a. KR-20
b. alpha

The means and standard deviations for each group on the number of examples received and post-, retention, and transfer test scores are reported in Table 2. These criterion measures were analyzed using a two-factor analysis of variance with objectives and rules as factors. The results with number of examples as criterion revealed a significant rule effect ($F = 106.48$, df = 1/129, $p < .001$) and a significant objective effect, ($F = 4.38$, df = 1/129, $p < .05$), wherein the presentation of rules and/or objectives reduced the number of examples required to learn the task.

Using posttest scores as criterion, a significant rule effect, ($F = 30.58$, df = 1/129, $p < .001$), and a significant objective effect, ($F = 3.95$, df = 1/129, $p < .05$), were obtained, where both rules and objectives increased posttest performance. Similar analyses conducted with retention test scores as criterion revealed a significant rule effect, ($F - 17.78$, df = 1/129, $p < .001$), with the rule groups obtaining the higher retention tests scores. No significant effects were obtained using transfer test scores as criterion.

The means and standard deviations for the four groups on the five latency criterion measures are found in Table 3. These latency measures also were analyzed using a two-factor analysis of variance. A significant rule effect was obtained for display latency ($F = 6.59$, df = 1/129, $p < .05$), and for test-item-response latency ($F = 12.01$, df = 1/129, $p < .01$) with the rule groups taking considerably less time to study the displays and respond to the criterion test items. Analyses using post-, retention, and transfer test-item-response latencies as

TABLE 2

Group Means and Standard Deviations for Number of Examples,

Post, Retention, and Transfer Tests

Group	Number of Examples		Posttest		Retention Test		Transfer Test	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Example Only	24.8	3.7	5.2	3.2	4.4	3.0	9.5	4.8
Objective-Example	23.1	5.0	6.7	4.6	5.5	4.2	9.3	4.8
Rule-Example	15.9	5.6	9.9	5.8	8.5	5.2	10.5	5.8
Objective-Rule	14.0	5.6	11.9	6.4	7.8	5.0	10.2	5.5

TABLE 3

Group Means and Standard Deviations for Display Latency Test-Item Response Latency, Post; Retention, and Transfer Test-Item-Response-Latencies

	Display Latency		Test-Item-Response Latency		Posttest-Item-Response Latency		Retention Test-Item-Response Latency		Transfer Test-Item-Response Latency	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Example Only	1226.3	504.9	656.9	297.2	292.7	147.8	336.8	134.4	440.7	162.2
Objective-Example	1254.9	468.1	578.9	217.8	369.5	171.7	352.9	143.8	413.6	182.1
Rule-Example	1106./	587.5	500.3	252.2	436.6	222.6	391.0	168.9	467.7	210.3
Objective-Rule	917.8	480.2	442.1	197.3	447.2	179.4	364.2	141.9	426.1	156.0

criteria yielded a significant rule effect for posttest latency ($F = 13.3$, $df = 1/129$, $p < .01$), where the presentation of rules increased the amount of time Ss spent on the posttest. No significant differences were obtained on either retention or transfer tests-item-response latencies.

Regression analyses of the individual ability scores, A-Trait scores, and the criterion measures were conducted. However, no significant ability by treatment interactions were obtained.

The means and standard deviations on the pre-task, mid-task, and post-task A-State scales for the four experimental groups are presented in Table 4. These data were evaluated by a three-factor analysis of variance in which objectives, rules, and task periods were the independent variables with repeated measures on the last factor. The results of this analysis revealed a significant period effect, ($F = 28.53$, $df = 2/258$, $p < .01$) with the level of A-State generally increasing across periods, and a significant rule by period interaction, ($F = 4.24$, $df = 2/258$, $p < .05$). A graph of the interaction is found in Figure 3. An analysis of covariance with mid-task A-State scores and post-task A-State scores as criteria and pre-task A-State scores as the covariate resulted in a significant rule effect ($F = 4.24$, $df = 2/258$, $p < .05$) on mid-task A-State. No effect was obtained on post-task A-State. These results revealed that presentation of rules for the first four modules reduced the level of A-State for the rule groups while A-State increased over the same period for those who were given no rules. However, the level of A-State for the rule groups increased to about the same level as the other groups at the completion of the eighth module.

TABLE 4

Group Means and Standard Deviations for the A-State Scale of the State-Trait Anxiety Inventory

Groups		Pre-Task A-State	Mid-Task A-State	Post-Task A-State
Example Only	Mean	9.2	10.2	12.7
	SD	3.5	4.8	5.5
Objective-Example	Mean	9.5	9.8	11.6
	SD	4.1	4.1	5.3
Rule-Example	Mean	10.3	9.3	11.8
	SD	2.6	3.0	4.3
Objective-Rule Example	Mean	10.1	8.6	11.3
	SD	2.9	3.1	4.3

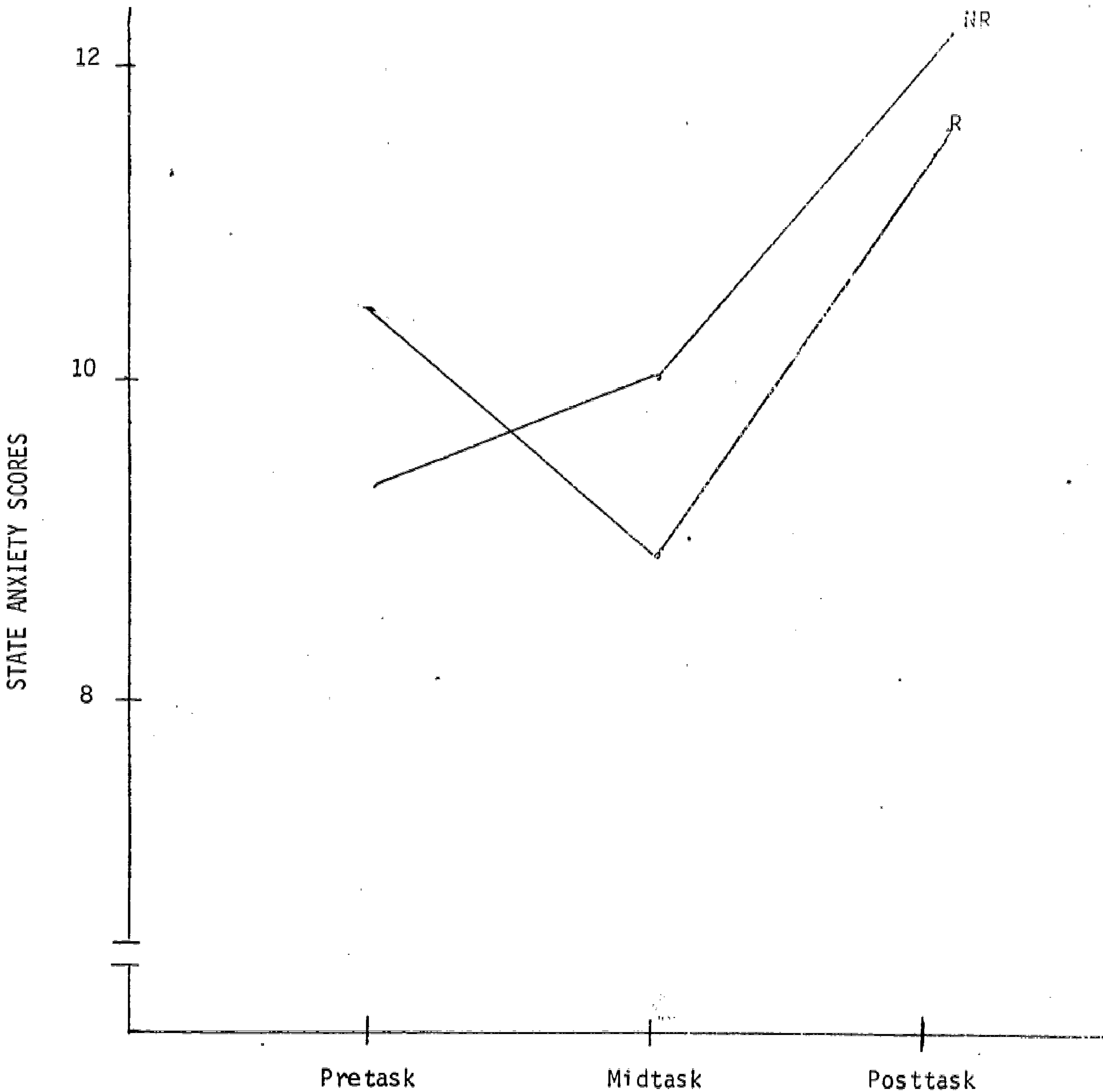

Figure 2.--Interaction of Periods of Test Administration and No-Rule (NR) and Rule (R) Treatments with State Anxiety Score Means as Criterion

Discussion

The purpose of this study was to replicate and extend an earlier study by Merrill (1970), where the interactive effects of objectives and/or rules on the learning process were investigated using an imaginary science. On the basis of the results from the earlier study, it was hypothesized that rules and objectives would decrease the number of examples required to reach criterion performance on the new learning task. The results from the present study confirm the hypothesis and thereby replicate the findings of the earlier study. Results from both studies indicate that the presentation of verbal statements of [illegible] enable most Ss to learn the task with a minimum number of examples. The availability of objectives has a similar but less pronounced effect.

Since the experimental procedure required all subjects to perform at a minimum criterion level on each rule before proceeding to the next, no group mean differences were expected on the posttest. However, the difficulty of the last four rules prevented several Ss from reaching criterion before all 5 examples were exhausted. An analysis of the Ss who failed to reach criterion revealed that the percentage of misses for the example-only, objective-example, rule-example, and objective-rule-example groups were 37.5, 29.2, 11.4, and 9.5 percent, respectively. Therefore, the significant differences on the posttest may reflect the fact that many Ss did not reach criterion level performance on some of the rules before proceeding to the following rule.

The hypothesis that the availability of rules would increase performance on the transfer test was not supported by the results

Inasmuch as all Ss did not reach criterion performance on the original task, it is difficult to interpret their performance on the transfer test.

The significant rule effect on the latency measures replicates the findings of the earlier study and demonstrates that the availability of rules reduces the amount of time required to study the example displays and respond to criterion test items. However, the hypothesis that objectives would reduce test item response latency was not replicated in this study.

It was hypothesized that the availability of rules would decrease post-, retention, and transfer latency. However, the results showed that rules actually increased posttest latency. This unexpected result may be due to a higher frequency of guessing for the no-rule groups.

The significant periods effect with A-state scores as the repeated measure supports the results found in earlier studies (O'Neil, 1970; O'Neil, Hansen, & Spielberger, 1969) wherein state anxiety is increased as the difficulty of the task increases. The significant rule by periods interaction supports the hypothesis that the availability of rules reduces A-State within the task. The increase in the A-State level for the rule groups after the initial decrease may indicate that the availability of rules may be more effective in reducing A-State for easy rules than for difficult rules.

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APPENDIX A

INSTRUCTIONAL MATERIALS

APPENDIX A: MATERIALS

MATERIALS FOR RULE 1

RULE

IF V IS A STRING OF NUMBERS, ρV GIVES THE NUMBER OF ELEMENTS IN THE STRING.

OBJECTIVE

GIVEN 3 *PROBLEMS WITH OPERATION* ρ *AND A STRING OF NUMBERS, V, YOU WILL COMPUTE* ρ*V FOR AT LEAST* 2 *PROBLEMS.*

EXAMPLE 1: ρ2 31 4 17 *GIVES* 4

TEST ITEM 1: ρ25 43 *GIVES* __________

TEST ITEM 2: ρ0 1 2 *GIVES* __________

TEST ITEM 3: ρ2 0 0 1 *GIVES* __________

EXAMPLE 2: ρ123 456 *GIVES* 2

TEST ITEM 1: ρ28 13 21 *GIVES* __________

TEST ITEM 2: ρ0 1 2 3 4 *GIVES* __________

TEST ITEM 3: ρ4 800 *GIVES* __________

EXAMPLE 3: ρ28 289 2889 *GIVES* 3

TEST ITEM 1: ρ236 0 14 *GIVES* __________

TEST ITEM 2: ρ170 17 170 17 *GIVES* __________

TEST ITEM 3: ρ100 1000 *GIVES* __________

EXAMPLE 4: ρ0 1 2 3 *GIVES* 4

TEST ITEM 1: ρ17 15 12 2 7 *GIVES* __________

TEST ITEM 2: ρ1 2 3 *GIVES* __________

TEST ITEM 3: ρ1 0 2 0 3 0 4 *GIVES* __________

EXAMPLE 5: ρ27 72 31 13 4 *GIVES* 5

TEST ITEM 1: ρ3 7 2 *GIVES* __________

TEST ITEM 2: ρ0 1 11 3 8 1 *GIVES* __________

TEST ITEM 3: ρ0 1 *GIVES* __________

MATERIALS FOR RULE 2

RULE

IF N IS A WHOLE NUMBER LARGER THAN ZERO, ιN GIVES A STRING OF THE FIRST N WHOLE NUMBERS LARGER THAN ZERO.

OBJECTIVE

GIVEN 3 *PROBLEMS WITH OPERATION* ι *AND A WHOLE NUMBER, N, YOU WILL COMPUTE* ι*N FOR AT LEAST* 2 *PROBLEMS.*

EXAMPLE 1: ι12 *GIVES* 1 2 3 4 5 6 7 8 9 10 11 12

TEST ITEM 1: ι4 *GIVES* __________

TEST ITEM 2: ι10 *GIVES* __________

TEST ITEM 3: ι1 *GIVES* __________

EXAMPLE 2: ι16 *GIVES*
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

TEST ITEM 1: ι8 *GIVES* __________

TEST ITEM 2: ι3 *GIVES* __________

TEST ITEM 3: ι14 *GIVES* __________

EXAMPLE 3: ι13 *GIVES* 1 2 3 4 5 6 7 8 9 10 11 12 13

TEST ITEM 1: ι9 *GIVES* __________

TEST ITEM 2: ι5 *GIVES* __________

TEST ITEM 3: ι11 *GIVES* __________

EXAMPLE 4: ι15 *GIVES*
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

TEST ITEM 1: ι7 *GIVES*

TEST ITEM 2: ι2 *GIVES*

TEST ITEM 3: ι6 *GIVES*

EXAMPLE 5: ι11 *GIVES* 1 2 3 4 5 6 7 8 9 10 11

TEST ITEM 1: ι4 *GIVES*

TEST ITEM 2: ι14 *GIVES*

TEST ITEM 3: ι8 *GIVES*

MATERIALS FOR RULE 3

RULE

IF V IS A STRING OF NUMBERS +/V GIVES THE SUM OF THE NUMBERS.

OBJECTIVE

GIVEN 3 PROBLEMS WITH OPERATION +/ AND A STRING OF NUMBERS, V, YOU WILL COMPUTE +/V FOR AT LEAST 2 PROBLEMS.

EXAMPLE 1: +/2 3 6 2 GIVES 13

TEST ITEM 1: +/1 3 2 GIVES --------

TEST ITEM 2: +/0 2 GIVES --------

TEST ITEM 3: +/12 23 1 GIVES --------

EXAMPLE 2: +/2 0 3 1 GIVES 6

TEST ITEM 1: +/3 0 2 3 GIVES --------

TEST ITEM 2: +/1 1 GIVES --------

TEST ITEM 3: +/2 0 0 GIVES --------

EXAMPLE 3: +/2 4 GIVES 6

TEST ITEM 1: +/10 100 3 GIVES --------

TEST ITEM 2: +/2 5 4 1 GIVES --------

TEST ITEM 3: +/2 2 2 GIVES --------

EXAMPLE 4: +/2 1 0 1 ***GIVES*** 4

TEST ITEM 1: +/3 2 4 ***GIVES*** --------

TEST ITEM 2: +/0 1 3 5 2 ***GIVES*** --------

TEST ITEM 3: +/1 2 3 4 5 ***GIVES*** --------

EXAMPLE 5: +/100 10 1 ***GIVES*** 111

TEST ITEM 1: +/5 5 *GIVES* --------

TEST ITEM 2: +/4 7 3 *GIVES* --------

TEST ITEM 3: +/0 1 2 3 4 5 ***GIVES*** --------

MATERIALS FOR RULE 4

RULE

IF V IS A STRING OF NUMBERS, ⌈/V GIVES THE LARGEST NUMBER OF THE STRING.

OBJECTIVE

GIVEN 3 PROBLEMS WITH OPERATION ⌈/ AND A STRING OF NUMBERS, V, YOU WILL COMPUTE ⌈/V FOR AT LEAST 2 PROBLEMS

EXAMPLE 1: ⌈/2 3 0 1 GIVES 3

TEST ITEM 1: ⌈/1 2 0 2 GIVES ________

TEST ITEM 2: ⌈/1 3 0 GIVES ________

TEST ITEM 3: ⌈/23 12 1 GIVES ________

EXAMPLE 2: ⌈/2 0 1 GIVES 2

TEST ITEM 1: ⌈/3 0 2 GIVES ________

TEST ITEM 2: ⌈/3 31 33 31 GIVES ________

TEST ITEM 3: ⌈1 2 3 4 GIVES ________

EXAMPLE 3: ⌈/4 5 3 2 GIVES 5

TEST ITEM 1: ⌈/101 107 111 11 GIVES ________

TEST ITEM 2: ⌈/5 5 4 4 4 GIVES ________

TEST ITEM 3: ⌈/4 2 0 10 3 GIVES ________

EXAMPLE 4: ⌈/2 3 2 5 4 3 2 *GIVES* 5

TEST ITEM 1: ⌈/2 1 1 *GIVES* --------

TEST ITEM 2: ⌈/4 3 2 2 4 3 3 *GIVES* --------

TEST ITEM 3: ⌈/2 1 3 2 3 *GIVES* --------

EXAMPLE 5: ⌈/0 100 21 25 *GIVES* 100

TEST ITEM 1: ⌈/10 100 3 *GIVES* --------

TEST ITEM 2: ⌈/2 + 3 + 5 1 4 *GIVES* --------

TEST ITEM 3: ⌈/5 4 3 2 *GIVES* --------

MATERIALS FOR RULE 5

RULE

IF V IS A STRING OF NUMBERS AND S IS A WHOLE NUMBER, S↓V GIVES A STRING CONTAINING ALL BUT THE FIRST S ELEMENTS OF V.

OBJECTIVE

GIVEN 3 PROBLEMS WITH OPERATIONAL ↓, A WHOLE NUMBER, S, AND A STRING OF NUMBERS V, YOU WILL COMPUTE S↓V FOR AT LEAST 2 PROBLEMS.

EXAMPLE 1: 2↓4 1 3 6 2 *GIVES* 3 6 2

TEST ITEM 1: 3↓9 6 8 4 7 *GIVES* __________

TEST ITEM 2: 1↓6 8 10 3 5 7 *GIVES* __________

TEST ITEM 3: 5↓1 2 3 4 5 6 *GIVES* __________

EXAMPLE 2: 4↓[illegible] 4 3 2 1 *GIVES* 1

TEST ITEM 1: 1↓2 8 3 *GIVES* __________

TEST ITEM 2: 4↓2 4 6 8 10 12 14 *GIVES* __________

TEST ITEM 3: 3↓1 2 1 3 1 4 *GIVES* __________

EXAMPLE 3: 1↓3 5 8 7 *GIVES* 5 8 7

TEST ITEM 1: 2↓3 3 4 5 *GIVES* __________

TEST ITEM 2: 5↓0 1 2 3 4 5 *GIVES* __________

TEST ITEM 3: 3↓1 2 3 4 5 6 *GIVES* __________

EXAMPLE 4: 3↓5 4 3 2 1 ***GIVES*** 2 1

TEST ITEM 1: 5↓54 3 2 1 0 ***GIVES*** ---------

TEST ITEM 2: 2↓1 0 0 0 ***GIVES*** ---------

TEST ITEM 3: 3↓1 0 1 2 3 4 ***GIVES*** ---------

EXAMPLE 5: 5↓1 3 2 4 9 7 6 8 ***GIVES*** 7 6 8

TEST ITEM 1: 2↓3 1 2 ***GIVES*** ---------

TEST ITEM 2: 4↓6 5 4 3 2 1 0 ***GIVES*** ---------

TEST ITEM 3: 1↓0 1 2 3 4 ***GIVES*** ---------

MATERIALS FOR RULE 6

RULE

IF A AND B ARE STRINGS OF NUMBERS, A+.×B GIVES THE SUM OF THE PRODUCTS OF THE CORRESPONDING ELEMENTS OF A AND B.

OBJECTIVE

GIVEN 3 PROBLEMS WITH OPERATION +.×, A PAIR OF STRINGS OF NUMBERS, A AND B, YOU WILL COMPUTE A+.×B FOR AT LEAST 2 PROBLEMS.

EXAMPLE 1: 1 2+.×5 3 GIVES 11

TEST ITEM 1: 1 0 3+.×2 4 1 GIVES ---------

TEST ITEM 2: 0 0+.×1 3 GIVES ---------

TEST ITEM 3: 2 3+.×2 1 GIVES ---------

EXAMPLE 2: 2 3 2+.×3 4 2 GIVES 22

TEST ITEM 1: 0 4 0+.×3 0 1 GIVES ---------

TEST ITEM 2: 2 3+.×1 2 GIVES ---------

TEST ITEM 3: 0 5 0+.×0 5 1 GIVES ---------

EXAMPLE 3: 3 2+.×0 2 GIVES 4

TEST ITEM 1: 1 5+.×5 0 GIVES ---------

TEST ITEM 2: 2 3+.×2 3 GIVES ---------

TEST ITEM 3: 1 2 3+.×3 2 1 GIVES ---------

EXAMPLE 4: 1 2 3+.×2 3 1 *GIVES* 11

TEST ITEM 1: 1 0 1+.×0 1 0 *GIVES* ---------

TEST ITEM 2: 1 5+.×2 3 *GIVES* ---------

TEST ITEM 3: 0 1 2 4+.×4 3 2 0 *GIVES* ---------

EXAMPLE 5: 2 4 3+.×5 3 2 *GIVES* 28

TEST ITEM 1: 1 0 2+.×0 9 3 *GIVES* ---------

TEST ITEM 2: 1 1 2 2+.×1 1 0 1 *GIVES* ---------

TEST ITEM 3: 5 4+.×3 2 *GIVES* ---------

MATERIALS FOR RULE 7

RULE

IF V IS A STRING OF NUMBERS AND S IS A WHOLE NUMBER, SΦV GIVES A STRING WHERE THE ELEMENTS OF V ARE ROTATED CIRCULARLY S ELEMENTS TO THE LEFT.

OBJECTIVE

GIVEN 3 PROBLEMS WITH OPERATION Φ, A WHOLE NUMBER S, AND A STRING OF NUMBERS V, YOU WILL COMPUTE SΦV FOR AT LEAST 2 PROBLEMS.

EXAMPLE 1: 4Φ5 12 6 13 7 14 GIVES 7 14 5 12 6 13

TEST ITEM 1: 2Φ2 3 4 5 GIVES ________

TEST ITEM 2: 7Φ5 10 15 20 GIVES ________

TEST ITEM 3: 1Φ1 2 3 4 5 GIVES ________

EXAMPLE 2: 1Φ21 32 45 GIVES 32 45 21

TEST ITEM 1: 3Φ2 3 4 5 GIVES ________

TEST ITEM 2: 0Φ7 1 6 5 GIVES ________

TEST ITEM 3: 4Φ1 2 3 4 5 6 GIVES ________

EXAMPLE 3: 2Φ6 14 8 GIVES 8 6 14

TEST ITEM 1: 3Φ9 8 7 6 5 GIVES ________

TEST ITEM 2: 4Φ35 28 3 2 GIVES ________

TEST ITEM 3: 2Φ2 0 1 0 GIVES ________

EXAMPLE 4: 3Φ1 3 2 4 5 *GIVES* 4 5 1 3 2

TEST ITEM 1: 1Φ2 3 4 5 *GIVES* ---------

TEST ITEM 2: 4Φ2 1 3 *GIVES* ---------

TEST ITEM 3: 2Φ7 3 3 1 *GIVES* --------

EXAMPLE 5: 5Φ4 3 2 *GIVES* 2 4 3

TEST ITEM 1: 1Φ15 20 25 30 *GIVES* ---------

TEST ITEM 2: 3Φ1 2 3 *GIVES* ---------

TEST ITEM 3: 5Φ3 1 *GIVES* ---------

MATERIALS FOR RU[illegible] 9

RULE

IF [illegible] A STRING OF NUMBERS, ΔV GIVES THE [illegible] THE ELEMENTS OF V WHICH WOULD SELECT THE ELEMENTS [illegible] ORDER

OBJECTIVE

GIVEN [illegible] WITH OPERATION Δ AND A STRING [illegible] [illegible] PAST 2 PROBLEMS.

[illegible] 1: Δ [illegible] GIVES 2 3 5 4 1

[illegible]M 1: Δ[illegible] GIVES ________

[illegible]EM 2: Δ[illegible] GIVES ________

[illegible]M 3: Δ[illegible] GIVES ________

EXAMPLE 2: Δ4 [illegible] GIVES 3 1 2 5 4

TEST ITEM 1: Δ[illegible] GIVES ________

TEST ITEM 2: Δ[illegible] 6 GIVES ________

TEST ITEM 3: Δ5 2 1 3 GIVES ________

EXAMPLE 3: Δ6 3 9 [illegible] 4 GIVES 1 2 5 4 3

TEST ITEM 1: Δ5 2 GIVES ________

TEST ITEM 2: Δ6 5 3 4 1 GIVES ________

TEST ITEM 3: Δ7 8 6 1 GIVES ________

EXAMPLE 4: ⍋3 10 5 1 *GIVES* 4 1 3 2

TEST ITEM 1: ⍋23 12 9 22 *GIVES*

TEST ITEM 2: ⍋0 3 7 1 4 *GIVES*

TEST ITEM 3: ⍋6 8 9 10 *GIVES*

EXAMPLE 5: ⍋8 3 0 6 *GIVES* 3 2 4 1

TEST ITEM 1: ⍋10 100 1 1000 *GIVES*

TEST ITEM 2: ⍋6 5 4 3 2 1 *GIVES*

TEST ITEM 3: ⍋2 8 5 6 9 *GIVES*

APPENDIX B

TESTS

POSTTEST

1. +/2 1 6 *GIVES* --------

2. ⌈/5 4 25 9 17 *GIVES* --------

3. 10 2 3+.×3 0 1 *GIVES* --------

4. 4⌽3 1 6 2 9 *GIVES* --------

5. ⍋2 7 9 1 3 *GIVES* --------

6. ρ3 5 1 4 2 *GIVES* --------

7. ⍳9 *GIVES* --------

8. 2↓9 8 7 *GIVES* --------

9. ⍋0 3 1 2 *GIVES* --------

10. ρ3 4 5 0 2 *GIVES* --------

11. +/1 2 3 4 5 6 *GIVES* --------

12. 5↓6 1 2 4 3 2 8 10 *GIVES* --------

13. 3⌽3 1 6 2 9 *GIVES* --------

14. ⍳2 *GIVES* --------

15. ⌈/5 1 4 3 *GIVES* --------

16. 2 1 3+.×1 2 3 *GIVES*

----

17. ⍋5 3 0 2 4 *GIVES*

----

18. 1↓3 2 1 0 *GIVES*

----

19. 1 1+.×9 3 *GIVES*

----

20. ⍴15 24 *GIVES*

----

21. +/10 2 10 *GIVES*

----

22. 0⌽9 6 1 3 *GIVES*

----

23. ⍳4 *GIVES*

----

24. ⌈/0 8 3 2 *GIVES*

RETENTION TEST

1. ρ10 21 *GIVES* --------

2. ι7 *GIVES* --------

3. +/3 4 1 *GIVES* --------

4. ⌈/0 9 4 2 *GIVES* --------

5. ↓2 1 3 4 *GIVES* --------

6. 3 4 1+.×2 1 3 *GIVES* --------

7. 5⌽1 2 3 4 5 *GIVES* --------

8. ⍋2 1 7 3 4 *GIVES* --------

9. +/9 4 5 2 *GIVES* --------

10. ⌈/28 17 29 26 27 *GIVES* --------

11. 2↓1 7 6 5 9 *GIVES* --------

12. 2⌽ 0 3 1 4 *GIVES* --------

13. ρ1 0 2 3 5 1 *GIVES* --------

14. ι6 *GIVES* --------

15. 1 2 1 3+.×3 1 0 2 *GIVES* --------

16. ⍋3 1 2 4 *GIVES* --------

17. ⌈/15 4 *GIVES* --------

18. 0⌽8 6 *GIVES* --------

19. 10 100+.×3 4 *GIVES* --------

20. ⍋5 10 0 8 6 *GIVES* --------

21. ⍳2 *GIVES* --------

22. ⍳82 34 61 *GIVES* --------

23. +/0 1 2 3 4 5 *GIVES* --------

24. 1↓0 3 0 1 2 *GIVES* --------

TRANSFER TEST

TRANSFER ITEM 1

EXAMPLE 1: ⌈/4 3 2 1 7 *GIVES* 1
EXAMPLE 2: ⌈/2 6 4 3 72 6 *GIVES* 2

PROBLEM 1: ⌈/2 5 7 9 11 *GIVES*

PROBLEM 2: ⌈/4 0 3 1 7 *GIVES*

PROBLEM 3: ⌈/47 43 41 46 *GIVES*

TRANSFER ITEM 2

EXAMPLE 1: ×/ι4 *GIVES* 24
EXAMPLE 2: ×/ι6 *GIVES* 720

PROBLEM 1: ×/ι3 *GIVES*

PROBLEM 2: ×/ι3 *GIVES*

PROBLEM 3: ×/ι2 *GIVES*

TRANSFER ITEM 3

EXAMPLE 1: 2 7 9 1⌈3 4 8 1 *GIVES* 3 7 9 1
EXAMPLE 2: 3 0 5 4 ¯1⌈2 1 5 6 2 *GIVES* 3 1 5 6 2

PROBLEM 1: 3 1 2 4⌈3 2 1 3 *GIVES*

PROBLEM 2: 9 7 5 3⌈2 4 6 8 *GIVES*

PROBLEM 3: 25 4 32⌈21 3 32 *GIVES*

TRANSFER ITEM 4

EXAMPLE 1: ⍒7 2 6 1 3 *GIVES* 1 3 5 2 4
EXAMPLE 2: ⍒0 3 1 2 *GIVES* 2 4 3 1

PROBLEM 1: ⍒2 6 3 7 *GIVES*

PROBLEM 2: ⍒2 3 4 1 *GIVES*

PROBLEM 3: ⍒7 5 6 3 1 4 2 *GIVES*

TRANSFER ITEM 5

EXAMPLE 1: 2 4 9+.-2 3 5 *GIVES* 5
EXAMPLE 2: 9 7 6 4+.-8 5 3 2 *GIVES* 8

PROBLEM 1: 11 2 1+.-5 1 1 *GIVES*

PROBLEM 2: 2 0 5 3+.-1 0 4 1 *GIVES*

PROBLEM 3: 3 4 1+.-3 4 1 *GIVES*

TRANSFER ITEM 6

EXAMPLE 1: -3↓7 0 1 4 6 8 *GIVES* 7 0 1
EXAMPLE 2: -5↓4 3 1 5 6 0 4 *GIVES* 4 3

PROBLEM 1: -1↓2 1 3 6 *GIVES*

PROBLEM 2: -2↓9 7 5 *GIVES*

PROBLEM 3: -4↓2 4 3 0 2 1 *GIVES*

TRANSFER ITEM 7

EXAMPLE 1:   -3ϕ1 5 6 2 4   *GIVES*   6 2 4 1 5
EXAMPLE 2:   -5ϕ2 1 3   *GIVES*   1 3 2

PROBLEM 1:   -1ϕ4 2 0   *GIVES*

PROBLEM 2:   -4ϕ2 3 1 2   *GIVES*

PROBLEM 3:   -6ϕ1 2 8 1   *GIVES*

TRANSFER ITEM 8

EXAMPLE 1:   3↑5 6 4 1 2   *GIVES*   5 6 4
EXAMPLE 2:   5↑2 1 7 3 4 0 12   *GIVES*   2 1 7 3 4

PROBLEM 1:   2↑3 7 4 5   *GIVES*

PROBLEM 2:   1↑4 2 7 3   *GIVES*

PROBLEM 3:   3↑2 7 17   *GIVES*

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